THE DYNAMICS OF NEUROLOGICAL SYMPTOMS AND BRAIN BIOCURRENTS IN ELECTROTRAUMATIC PATIENTS

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The historical progress of the development in the study of electrotrauma in its aspects has duplicated in many ways the development of neurology, with particular reference to the fact that the wide-spread idea that the process caused by electric current is functional has gradually given place to recognition of the organic genesis of the affection. This has been helped by the establishment of a certain morphological basis, the introduction of more exact methods for examining patients, and finally, which is sometimes most basic, a dynamic study of the process in all its phases of the disease from the acute period to the most removed, residual one.

However, we must admit that quite frequently diagnosis of a patient is not easy, not only under the conditions prevailing in a polyclinic, but also in a more thorough clinical examination, especially in cases which are on the borderland of the organic and functional, the physiological and patho-physiological, where each time in the analysis of the clinical picture for such patients there arises the necessity to reinforce clinical examinations with more refined methods of examination and to carry out not only

a clinical but also a clinical-physiological analysis of the pathological process. With this purpose in mind, we employed, besides other methods of electrophysiological examination of patients, the electroencephalograph. Although we could not find any information in the wide range of literature dealing with different questions of electrotrauma, as well as in literature referring specifically to electrophysiology relating to the investigation of biocurrents of the brain of persons who had received trauma from electrical current, as indicated by many authors, produces first of all a marked disruption of the processes of stimulation and inhibition, but that it also must affect the electrical activity of the brain. We made a study of the brain biocurrents for 40 patients, who had suffered electrotrauma in everyday living or in industry. The electroencephalogram registered simultaneously two symmetrical sectors of both hemispheres. Silver electrodes were used for taking off the biocurrents; unipolar conduction of the current was made with an ordinary electrode attached to an ear lobe. The registering apparatus used was a Simens oscillograph. The electroencephalogram was recorded on photographic paper moving at the rate of 3 centimeters per second. Bioelectrical activity was shown to vary in the majority of cases. In this connection attention should be directed to considerable variability in the disruption of the electroencephalogram for different persons. Basically, the following changes took place: (1) disorganization or entire disappearance of the alpha rhythm, (2) a considerable decrease in the amplitude of fluctuation of the potentials (in most cases), (3) the appearance of needle-like, quickly-moving waves (rare), (4) the appearance of slow pathological waves, both regular and irregular, (5) reflection of

heart action on the electroencephalogram, (6) monotype quality of the lines of the electroencephalogram according to areas, (7) the appearance of asymmetry in the electroencephalogram for the two hemispheres or for similar regions.

We found it interesting to compare the data obtained from the electroencephalographic examination with the entire complex of clinical manifestations for the different stages of the process and to make use of this data for diagnostic purposes. We present several extracts from case histories.

Case 1. Patient L., 40 years old. Electrotrauma through contact with 380-volt alternating current through his hands. Did not lose consciousness. During acute period complained of slight headache. No objective manifestation of hypertension nor basic symptoms of disruption of the nervous system were disclosed. The electroencephalogram made on the day following the electrotrauma showed a considerable deviation from normal. The alpha rhythm was absent; all areas showed a prevalence of slow oscillations of the potential (5-6 per second), with a very small amplitude. Pattern on the electroencephalogram identical for different regions. Low electrical activity. Electroencephalogram of the same patient made fifteen days later was close to normal. The slow waves had disappeared; the alpha rhythm had reappeared (9 oscillations per second); the amplitude of oscillations for the potentials had increased.

We have just presented a case of light electrotrauma which did not involve loss of consciousness nor any after-effects for the brain as a whole or any local symptoms on the part of the nervous

system. But nevertheless it was possible to note a considerable change in the bioelectrical activity of the brain during the acute period on what would be considered a completely felicitous clinical picture.

This discrepancy between the findings of the clinic and of the electroencephalogram we consider to be only apparent, inasmuch as the electric current in traumatic conditions may not be considered to be a matter of indifference to the organism, regardless of how slight the shock may seem to be at first glance. According to the observations of many authors the nervous system is particularly sensitive to electric current. Vigdorchik explains this by saying that the biological action of current manifests itself in a change in the irritability of the nervous system and consequently that tissue which plays the main role in conducting stimuli, that is, the nervous system, is the first to react to current.

We can say on personal observation that electrical current is not a matter of indifference to the organism even in cases of light electrotrauma. We have quite frequently encountered cases of electrotrauma that took place without loss of consciousness and without show of any symptoms of organic affection of the nervous system during the acute period, but when such patients again came under our observation after a period of time, there could already be noticed symptoms of organic affection of the nervous system.

Case 2. Patient B. received electrotrauma through contact with a 1000-volt alternating current. The patient did not lose consciousness, and during the first few days after the accident,

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noticed that he had light headaches. No pathological manifestations could be objectively noticed in the neurological status. While observing biocurrents in the brain during this period certain changes were noted: an asymmetry of the electroencephalogram for the frontal and parietal regions and a low amplitude in the oscillations of the potentials. The patient was discharged after 8 days and went back to work. However, after a month's time he returned to the clinic with complaints of persistent headaches. After a course of dehydrative therapy an improvement took place and the patient was discharged. But he returned a third time to the clinic ten months later with complaints of the onset of acute, painful headaches which confined him to bed. Puncturing disclosed a high spinal fluid pressure (560 millimeters), while the pneumoencephalograph showed hydrocephalus of the lateral and third ventricles.

In this case there was noticed a progressive development for something which had appeared light during the acute period. It is interesting to note that in this case which seemingly was without any clinical symptoms, there was nevertheless noticed a slight pathology of the bioelectrical activity of the brain during the acute period.

A dynamic study of the entire complex of clinical manifestations and the results of the electroencephalographic investigation showed that in some cases pathological changes were of a temporary, lightly reversible character, other cases of a more lasting character, and, finally, in some cases there was noted a certain tendency toward an intensification of the pathology.

Electrotrauma accompanied by a deep loss of consciousness and a subsequent hypertensional syndrome generally brings on greater and more lasting changes in the electroencephalogram. Side by side with a diminishing of electrical activity in the brain observable in the majority of cases, there was also noticed an increase for some patients. Occasionally the electroencephalogram would show slow waves and oscillations of a pathological nature which coincided with the rhythm of the heart's contractions. Under normal conditions a stimulus arising in the heart muscle does not usually register through electrodes used for recording the biocurrents in the brain. But in the case of patients suffering from electrotrauma there seem to exist conditions which assist the transfer of impulses of stimuli arising in the heart muscle. We noted the rhythm of the heart's activity on electroencephalograms for all cases of severe electrotrauma, but, on the other hand, did not observe it in light cases. Let us give some examples of electrotrauma presenting more severe clinical pictures and with more lasting and definitely expressed changes in the electroencephalogram.

Case 3. Patient K., 23 years old, received an electrotrauma from a 550-volt alternating current through her right hand. She lost consciousness for 2½ hours. She was fully prostrated during the acute period; stupor (zagruzhennost') would alternate with periods of psychomotor excitement and completely irresponsible behavior. Manifestations of amnesia and a completely apathetic attitude toward her own condition were to be observed. Electroencephalograms were made while she was in a state of complete unconsciousness (Figure 1). The first thing that demands attention is the chaotic quality of the electroencephalogram, marked by the

absence of a definite rhythm. There are many slow irregular waves, emanating principally from the right hemisphere and especially from the occipital region. Electrical activity of the brain is very low. There is a marked change in the encephalogram in direct proportion to the return of consciousness. Slow oscillations are less frequent, of shorter duration and amplitude. In spite of the fact the patient was able to considerably dissimulate her condition -- was gay, active, and not complaining, -- there were noted visible disturbance of the sleeping rhythm, heightened somnolence, euphoria, and, as formerly, a certain irresponsibility of behavior. The patient was discharged at her own insistent demand on the tenth day following electrotrauma. The electroencephalogram was characterized during this period by the following special features: the alpha rhythm was absent. There prevailed for all regions irregular retarted waves against which the oscillations of the potentials were of low amplitude. Oscillations in rhythm with her heart action were quite clearly noticeable. After a 3-month interval the patient was recalled for a second examination. Her condition had considerably improved. She complained of the occurrence of severe headaches. Several times at the height of such headaches she had fainted.

Moreover, she showed a considerable weakening of the physical and psychic functions. It was not possible to notice a normalization of the electroencephalogram for this period. The amplitude of oscillations increased, but imperceptibly; oscillations of the potentials registering in time with the rhythm of the heart's contractions had become less marked. There were many slow waves emanating from the frontal and parietal regions.

A	B	C
a	a	a
b	b	b

Figure 1. Patient K. Electroencephalogram made several hours after the electrotrauma.

A - occipital region; B - parietal region; C - frontal region; a - left side; b - right side.

Case 4 belongs to the same group of persevering disturbances shown by the electroencephalogram.

Case 4. Patient G. The current was of unknown voltage. Contact took place through the hands. Her wrists showed second degree burns. She had numerous fainting spells. There was a disruption of her breathing and a cyanosis of her lips and face. She was then given artificial respiration. She continued to have severe headaches for several days. She was sluggish, comatose, and apathetic. There was noticed no marked pathology of the central nervous system. Hypertension of the vascular system was observed. An electroencephalogram made during the acute period showed an uneven character for the different regions. The occipital region showed a predominance of oscillations of low amplitude; they were used for measuring individual slow oscillations. The parietal region manifested a predominance of slow oscillations, the frontal region frequent oscillations of large amplitude (Figure 3). The appearance of frequent oscillations in this instance can be explained apparently by the flow of afferent impulses from the area of the burns. Four days later, when the condition of the patient had improved, but the

clinical picture as formerly was characterized by manifestations of hypertension, the electroencephalogram continued to preserve almost the same original appearance with the exception that oscillations in rhythm with the heart action had begun to manifest themselves.

After 2½ months the patient was discharged considerably improved. Her headaches were no longer persistent; their intensity had considerably decreased, but there was a manifestation of general adynamia. The electroencephalograms for this period still showed a considerable deviation from normal. The alpha rhythm was absent; against the background of beta waves of low amplitude there was recorded oscillations in rhythm with the heart action; variations in the pattern for the different regions were no longer apparent. Thus, disturbances in the picture of the electroencephalogram against the background of a satisfactory clinical condition served, as it were, as a harbinger of the normalization of functions which had as yet not taken place. This serves as an illustration of the fact that the disappearance of external clinical symptoms for the process is far from serving as evidence of its complete liquidation and takes place very frequently only as a temporary result of therapeutic measures and of the compensatory possibilities of the organism itself. That such is actually the case we have been able to convince ourselves many times from observation of other patients. Patients sometimes have been discharged from the clinic in a good condition without any symptoms of affection of the nervous system, but it was sufficient for some change in the situation to take place (working in mines, at heights, in a shop with high temperatures, on transport) for the apparent satisfactory condition to yield its place to some pathological syndrome.

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We have observed cases where changes in the electroencephalogram bear witness to pathological intensification, which fact in combination with the entire complex of clinical symptoms pointed to the continuation of the process.

A	B	C
a	a	a
b	b	b

Figure 2. Patient K. Electroencephalogram made 3 months after occurrence of electrotrauma.

A - occipital region; B - parietal region; C - frontal region; a - left side; b - right side.

A	B	C
a	a	a
b	b	b

Figure 3. Patient G. Electroencephalogram made several hours after occurrence of electrotrauma.

A - occipital region; B - parietal region; C - frontal region; a - left side; b - right side.

A	B	C
a	a	a
b	b	b

Figure 4. Patient I. Electroencephalogram made 1½ months after occurrence of electrotrauma.

A - occipital region; B - parietal region; C - frontal region; a - left side; b - right side.

Case 5. Patient I., 16 years old. Electrotrauma received from 120-volt alternating current through her hands. She lost consciousness twice for a long period of time. She complained of persistent headaches during the acute, sub-acute, and residual periods. Objectively, the patient looked comatose, inert, and labile. She produced high tendon reflexes and had an enlarged reflex zone for knee reflexes. There was a local asthenic syndrome in her upper extremities. She had hyperhidrosis, especially in the upper extremities. Blood pressure was 130/60, pulse 62 per minute. The electroencephalogram made on the fifth day was close to normal; there is only to be noticed a slight decrease in the amplitude of oscillations. The patient was discharged after 1½ months although her condition had remained extremely unstable (headaches occurred with hardly any provocation, pains would be felt in the limbs, temperature was subfebrile, at times she would feel a general weakness which she could not overcome). The electroencephalogram had changed considerably. The alpha rhythm was gone, there appeared irregular slow oscillations lasting 170-200 sigm, especially clearly expressed for the parietal region (Figure 4). The patient reentered the clinic a month later because of sharp headaches and fainting spells which took place when the headaches were at their highest peak and because of somnolence and adynamia. Her neurological status was marked by a slightly expressed hypokinetic syndrome. Particularly noticeable were facial amemia, heightened tendon reflexes, trembling of the fingers, emotional instability, a manifestation of vegetative asymmetry and considerable instability of vegetative reactions with predominance of the tone of the sympathetic nervous system. The psychic status indicated a weakness of

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the psychic functions. The electroencephalogram for this period showed signs of a pathological condition. Delta waves were recorded for all regions (Figure 5).

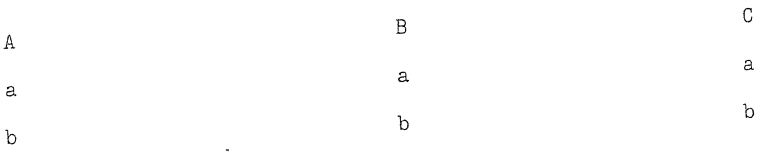

Figure 5. Patient I. Electroencephalogram made 2½ months after electrotrauma.

A - occipital region; B - parietal region; C - frontal region; a - left side; b - right side.

We have presented by way of illustration several different courses of the process that apparently vary in character.

Let us now make an analysis of those changes in the central nervous system which might have been responsible for the differing development of the process. Although in the conditions of industry or every-day life there always enter many unknowns with respect to electrotrauma (differences in type of current, its voltage, duration of contact with current, localization of contact, the morbid condition of the nervous system, etc), on the basis of numerous prolonged observations, we consider ourselves justified in presenting an opinion on the way electrical current affects the nervous system. In those cases where pathological manifestations, regardless of how numerous they may be, are of only a temporary, easily reversible character, its effect is apparently of a neurodynamic character and of a marked disturbance of the processes of stimulation and inhibition.

Except for extraordinarily great and extremely quick reversibility of pathological manifestations, it results in a marked disturbance of the entire equilibrium of the organism, including a change in the K/Ca ratio in the blood and especially in the spinal fluid (the coefficient of K/Ca in the fluid of one patient was 0.7, in another 3.2). This is corroborated by the record of the biocurrents in the cortex of the brain that sometimes indicate a considerable decrease in the electrical activity of the cortex of the brain and sometimes an increase.

In a number of cases, the reaction of the organism to the action of stimulus that the organism cannot cope with, which is the case for electrical current for conditions of trauma, is limited to the disturbance of the processes of stimulation and inhibition and does not result in lasting illness. But the functional and neurodynamic process has its substratum. This could be a change in the chemical factors of irritability, a change in the membranes of albumin structure, a disruption of penetrability, etc. This makes understandable the possibility of a transition from a functional neurodynamic process to a functional one at the basis of which there already lie microstructural, but more lasting, changes in the nervous system.

The growth of neurological symptoms, the progressive growth in modifications of the electroencephalogram, the appearance of pathological types of oscillations, and the absence of reversibility for these changes for prolonged intervals of time among some of our patients suffering from electrotrauma all point to the development of an organic affliction of the nervous system. Whether micro-structural changes of individual cell formations created by the

direct action of the current play a part here, or whether these changes take place as a result of the disruption of blood or spinal fluid dynamics cannot always be established.

Nevertheless the considerable dynamic quality of the process, especially where there is to be noted a quick remission of symptoms or, on the other hand, an intensification of the course, serves as a basis for supposing the existence of a disturbance of the vascular tone and of circulatory lymphatic disturbances. This is in complete accord with existent literature. It is possible that further evidence for this is to be found in those oscillations recorded on the electroencephalogram corresponding to the rhythm of the heart's action noticeable in severe cases of electrotrauma.

We already have indicated, while analyzing the cases of electrotrauma, the diagnostic value of the electroencephalographic method, especially for the very slight and limited cases where the decision of the question as to whether the process was of an organic or functional character proved to be difficult. Besides its theoretical significance the resolution of such a problem was of practical value from the point of view of selecting the method of therapy and a proper type of work for such patients.

The electroencephalographic method is of significance in the complex of clinical observations from the point of view of broadening our theoretical ideas. But we must nevertheless emphasize that as a more refined method it can establish for a number of cases the functional disruption of the activity of the central nervous system where it is not possible to do so with the usual clinical methods.

In the pathological study of the brain among diffused

changes a number of authors point out the primary interest of the region of the 3rd and 4th ventricles with respect to the vegetative centers. There are also to be noted significant changes in the region of subcortical formations. The syndrome of subcortical affections stands out very clearly in the clinic especially during the residual period.

There have been carried out recently a number of interesting experimental investigations relating to the study of cortical functions under the action of electrical current. Conditioned reflexes were studied with this in mind. All the experimenters noted changes in conditioned reflex action although they describe these changes and their operation quite differently. Thus, Skipin thinks that these changes take place as a result of the stimulation by the current of the vegetative centers of the brain and supports this by the fact that, first, there is a large number of vegetative reactions (expanded pupils, secretion of thick viscous saliva, tears, tachycardia, increased blood pressure, etc) observable under experimental conditions and, second, the fact that these changes in conditioned reflex action were to be noted when the sympathetic nodes were irritated.

In studying the higher nervous functions of dogs Podkopayev concluded that the conditioned reflex action in dogs, when influenced by electrical current, changes because of a direct decrease in the irritability of brain cortical cells.

All this shows that the problem of the operation of the influence of electrical current on the cortex of the brain in

electrotrauma has not yet been sufficiently studied and is in need of further clinical and experimental study. In this connection it is interesting to note that there is a simultaneous recording of biocurrents in the cortex of the brain and subcortical formations together with a deeper psychological analysis of the patient.

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